

Evaluation of CERES-MODIS Cloud Retrievals Using CALIOP Observations: Marine Low-Level Clouds

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Special Thanks to CALIPSO Group:

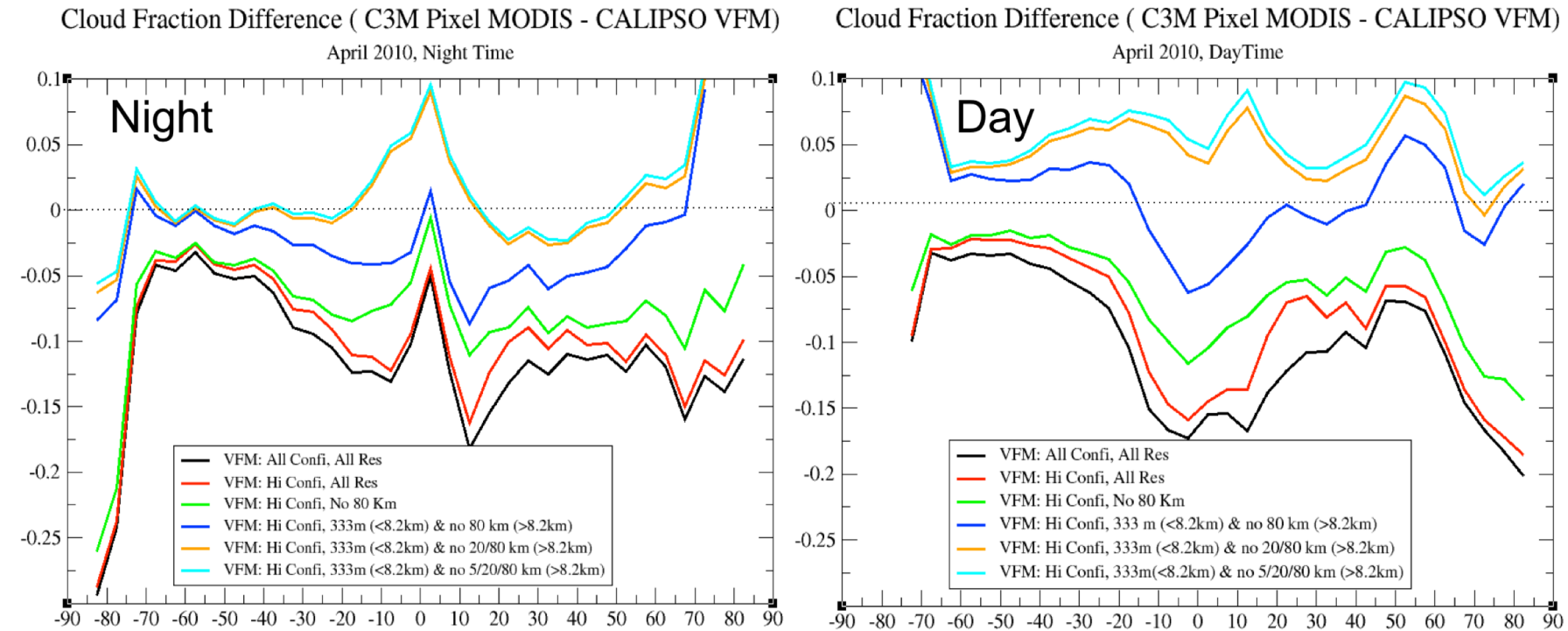
Dave Winker, Chip Trepte, Mark Vaughan, Xia Cai, Roman Kowch

Spring 2018 CERES Science Team Meeting

May 15-17, 2018

Hampton, VA

Previous Science Team Meeting



- **CALIPSO Vertical Feature Mask (VFM) reports cloud detections on a variety of spatial scales ranging from 333-m (single shot) to 80 km**
- **Lots of cloud fraction variability depending on the spatial scales used to determine cloud fraction**
- **MODIS cloud fraction higher than CALIOP when the most tenuous clouds are treated as clear-sky**
- **Concern that MODIS may over-detect clouds in marine cumulus/stratocumulus cloud fields**

Cloud Detection Assessment Working Group

- Cloud Detection Assessment Working Group formed at LaRC in Jan 2018
- CERES collaborating with CALIPSO team for advice and feedback regarding proper use of the data
- CALIPSO products are very complex and require careful consideration of horizontal averaging (HA) and quality flags
- Formed Working Group initially to analyze low clouds in detail but will examine other cloud types in the future

CALIPSO Horizontal Averaging Summary

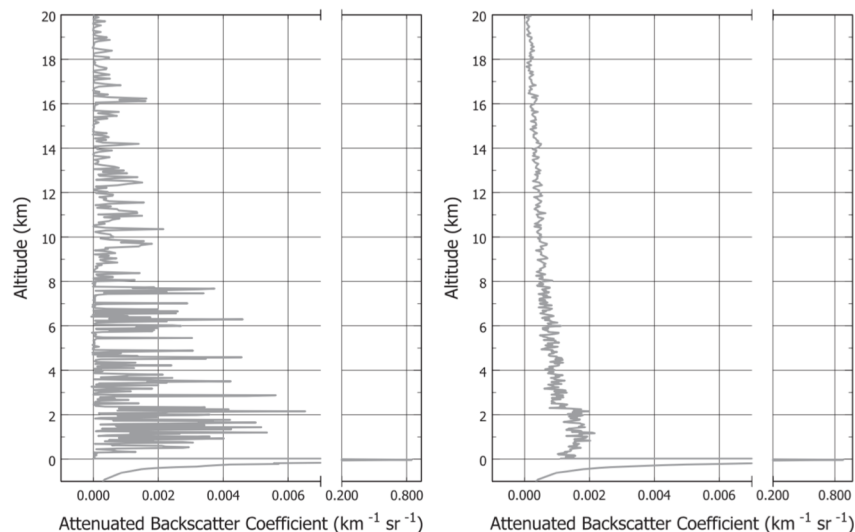


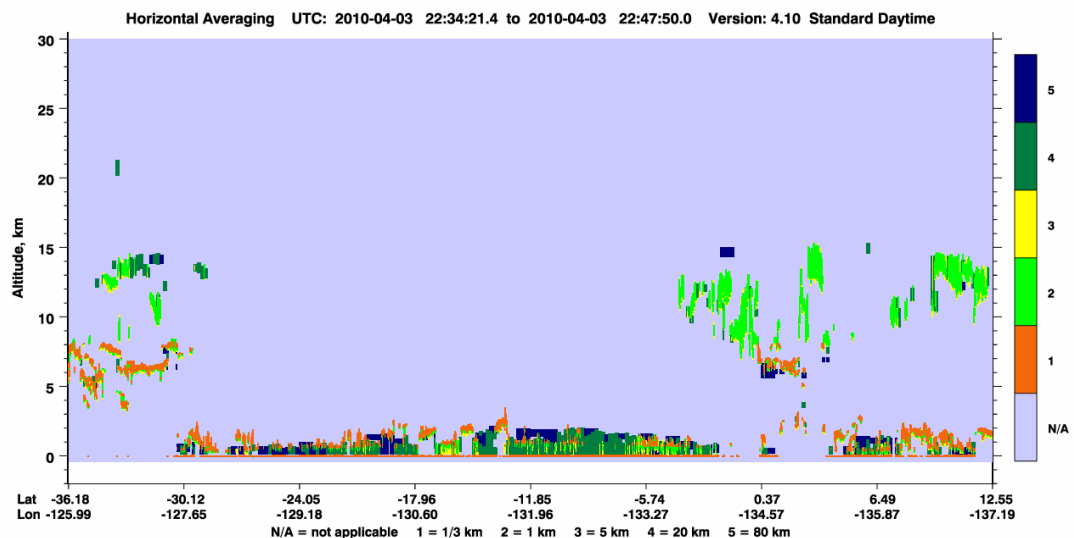
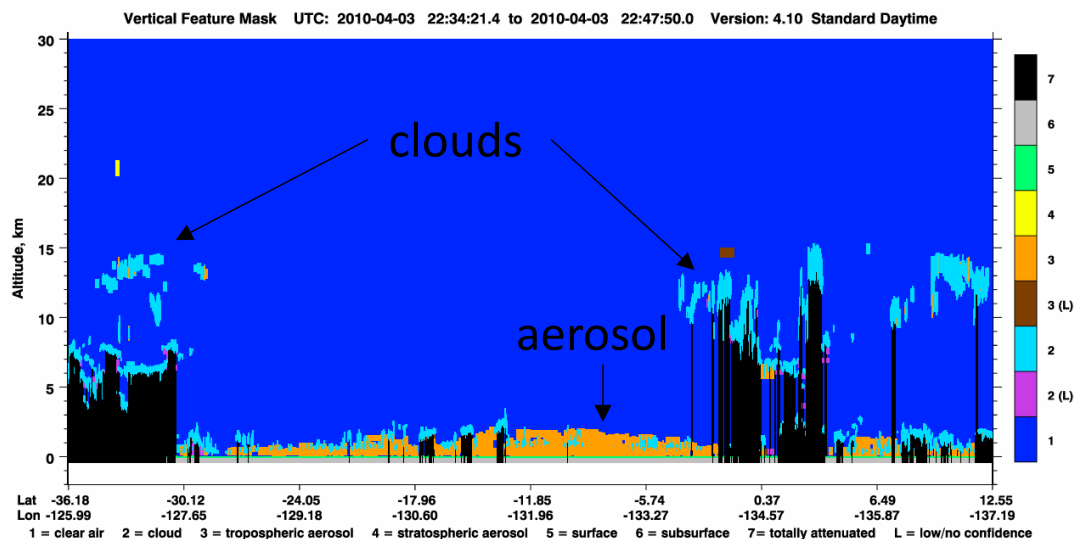
FIG. 2. (left) An example of the native SNR of the CALIOP data shown by a single, full-resolution 532-nm attenuated backscatter profile acquired 13 Aug 2006 at 19.2°S, 113.9°E; (right) the same data incorporated into a 20-km (60 profile) horizontal average. The aerosol layer at ~2.2 km is present in both profiles, but its presence only becomes apparent in the averaged data.

Fig. 2 from Vaughan et al. (2009, JAOT)

Single lidar shots have a footprint size of ~100m at the surface and are spaced 333 m apart.

Strongly scattering features (e.g., water clouds) are typically detectable with a single shot

Weak features (e.g., thin cirrus, aerosol layers) usually require some amount of horizontal averaging (HA) to detect

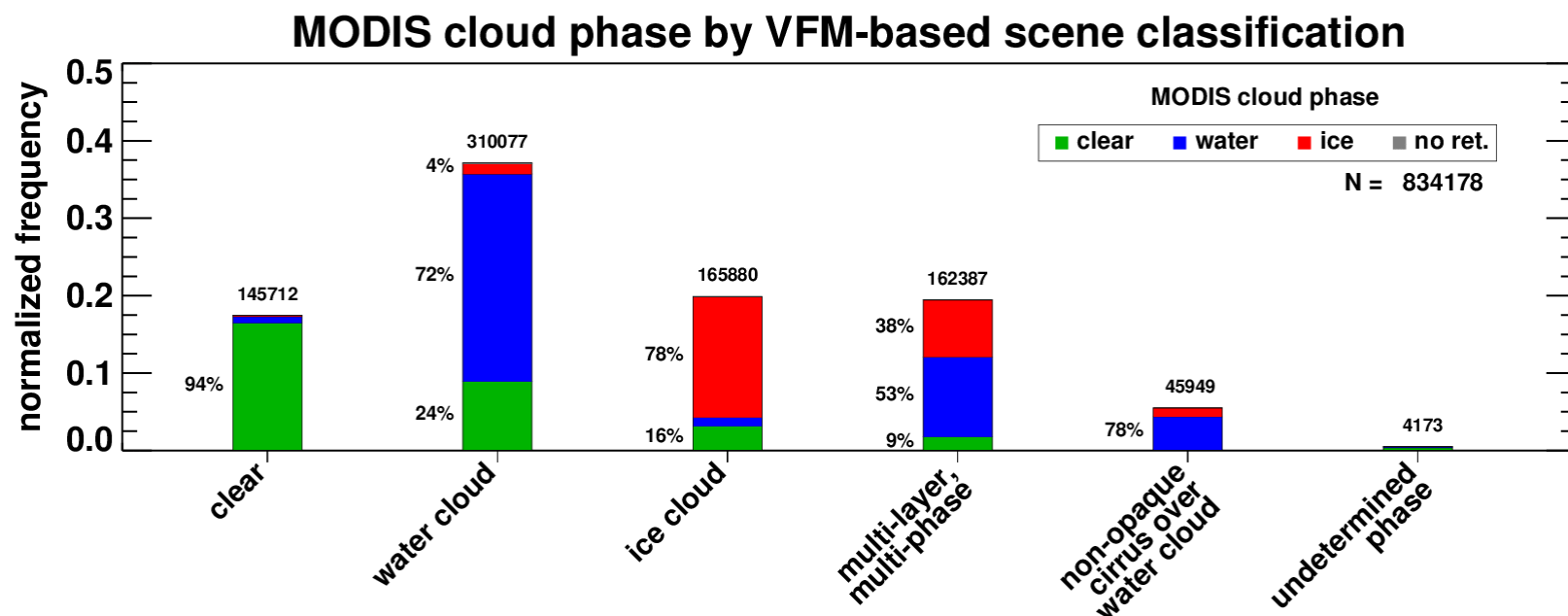


aka, "single-shot"

Collocated CALIOP/MODIS Dataset

- CALIPSO ground track broken into 5-km segments
 - 5-km spatial scale is the fundamental scale used by the CALIOP feature-finding algorithm
- Nearest MODIS pixel matched to the midpoint of each track segment
- CALIPSO products used:
 - Vertical Feature Mask (VFM): provides details about detected “features”, i.e., clouds and aerosols
 - 5-km Cloud Layers product: cloud top heights
- Some 5-km track segments are only partially cloud-filled. Single-shot detections provide “sub-segment” cloud fraction, or an estimate of cloud fraction

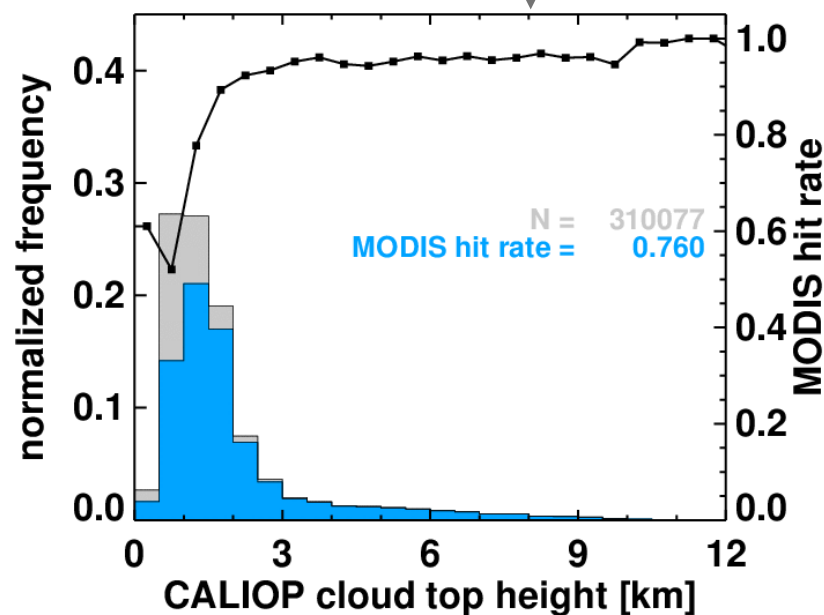
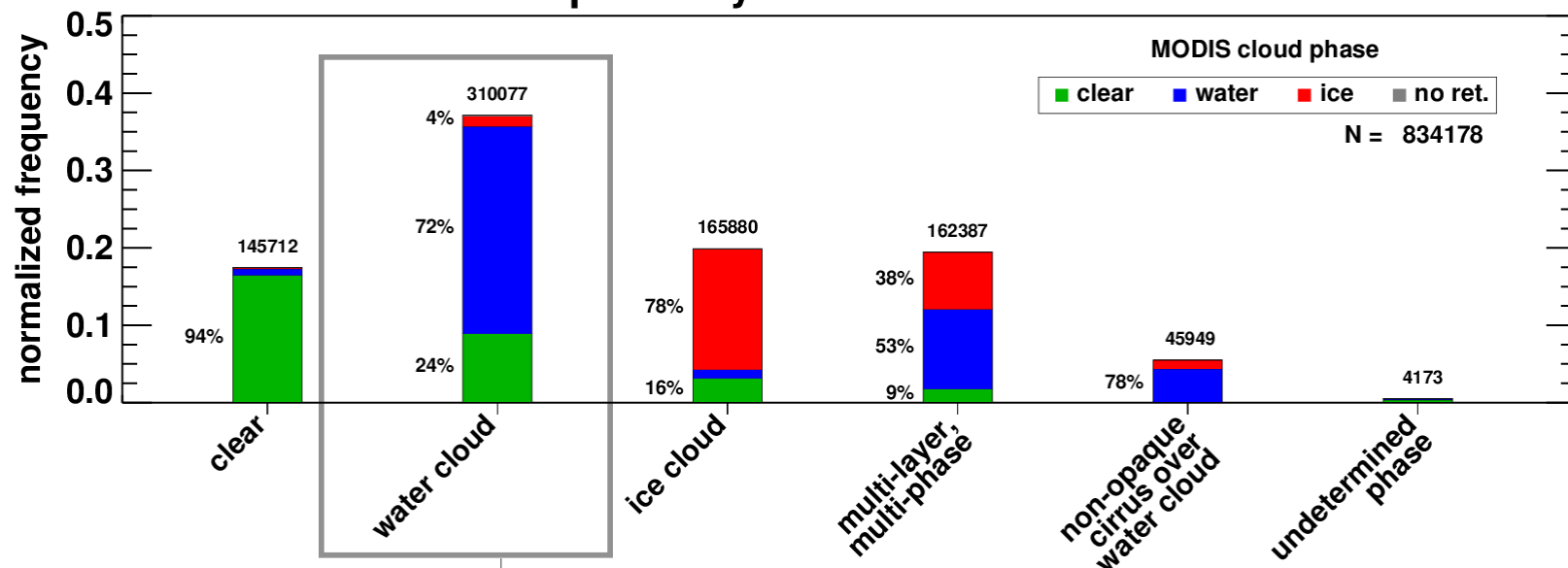
Cloud Mask/Phase Summary: April 2010



- Collocated CALIOP/MODIS data from April 2010 (non-polar, daytime, ocean surface)
- Scene classification determined from VFM product (x-axis labels) based on number of cloud layers and cloud phase
- MODIS cloud phase represented by colors indicated in the legend
- MODIS false detections comprise < 6% of the “clear” category and only ~1% of the entire April 2010 dataset
- Little evidence that MODIS cloud mask over-detects clouds

Cloud Mask/Phase Summary: April 2010

MODIS cloud phase by VFM-based scene classification



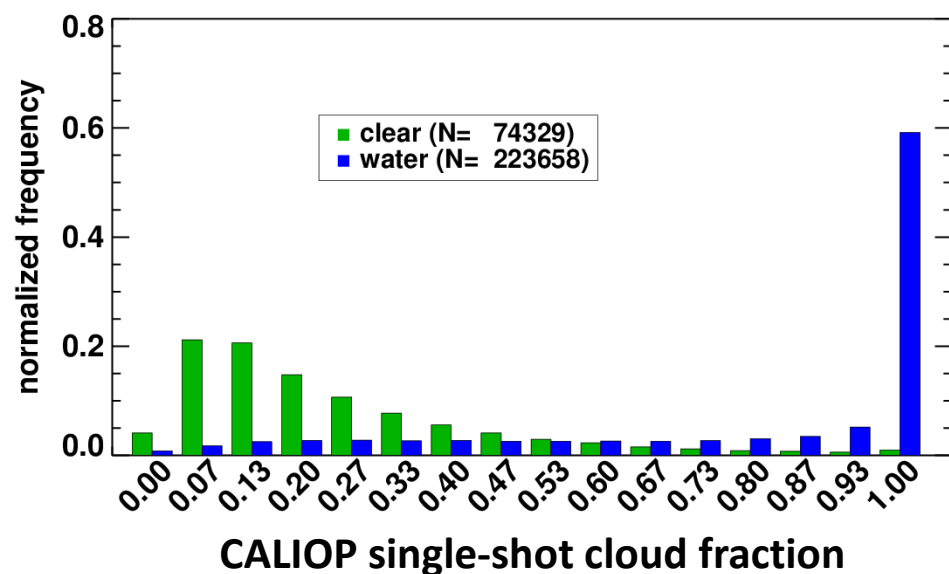
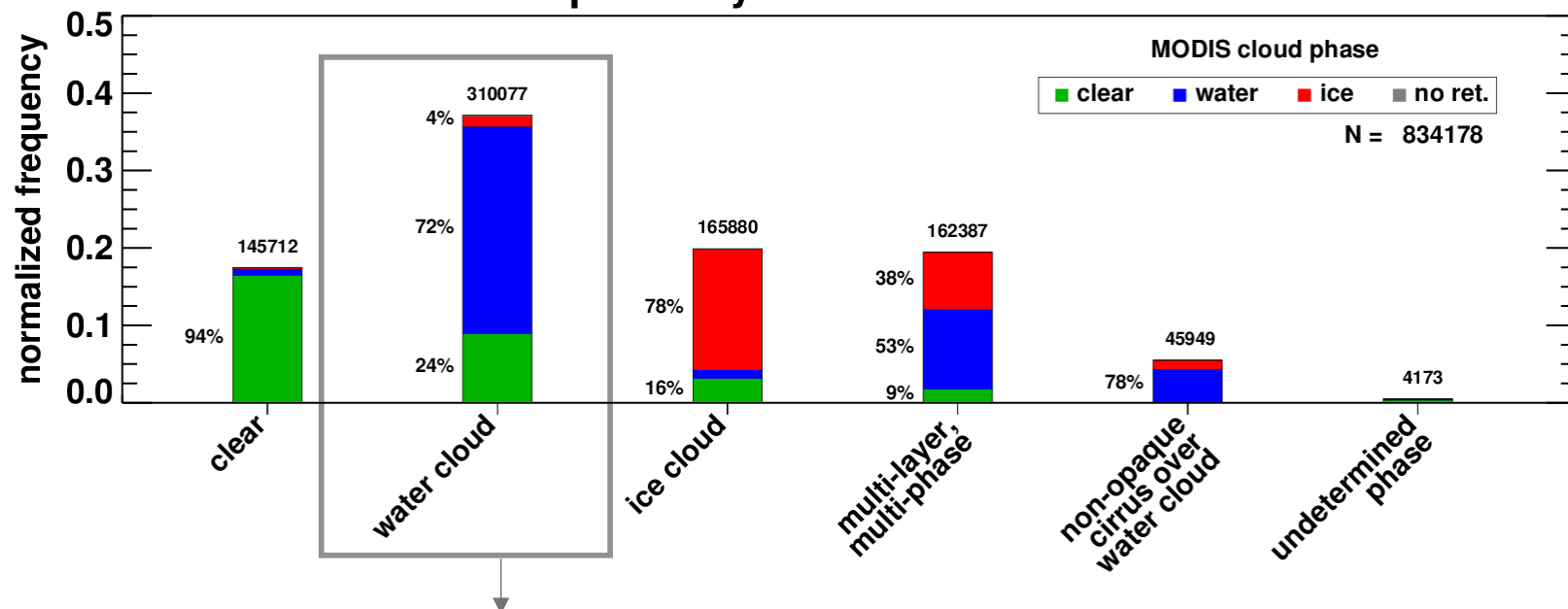
Blue PDF represents fraction of CALIOP clouds that MODIS detected

Black line: MODIS hit rate as a function of cloud top height (see right y-axis)

Undetected clouds have top heights < 2 km, characteristic of marine boundary layer clouds

Cloud Mask/Phase Summary: April 2010

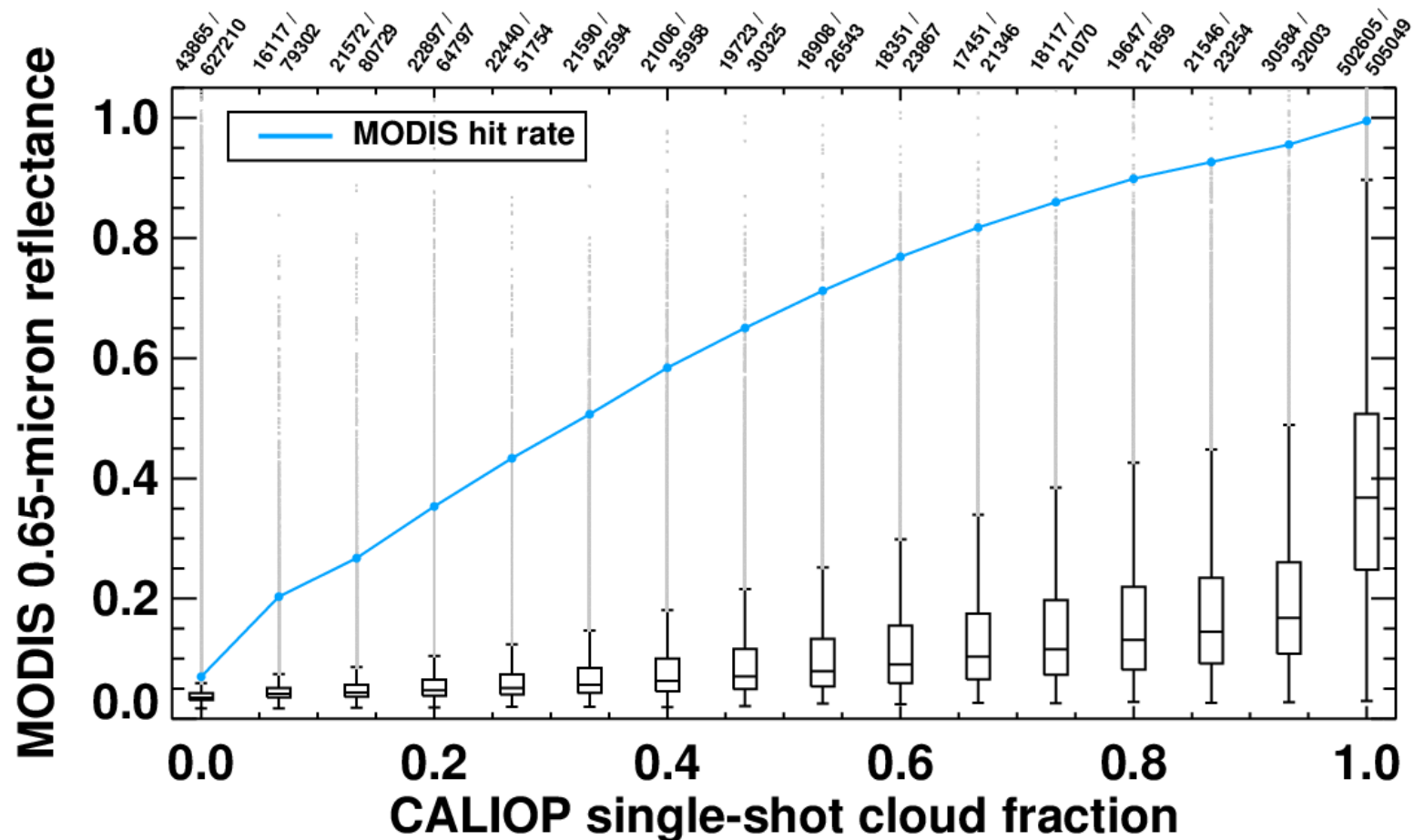
MODIS cloud phase by VFM-based scene classification



Most (~60%) of the detected water clouds (blue bars) were overcast scenes

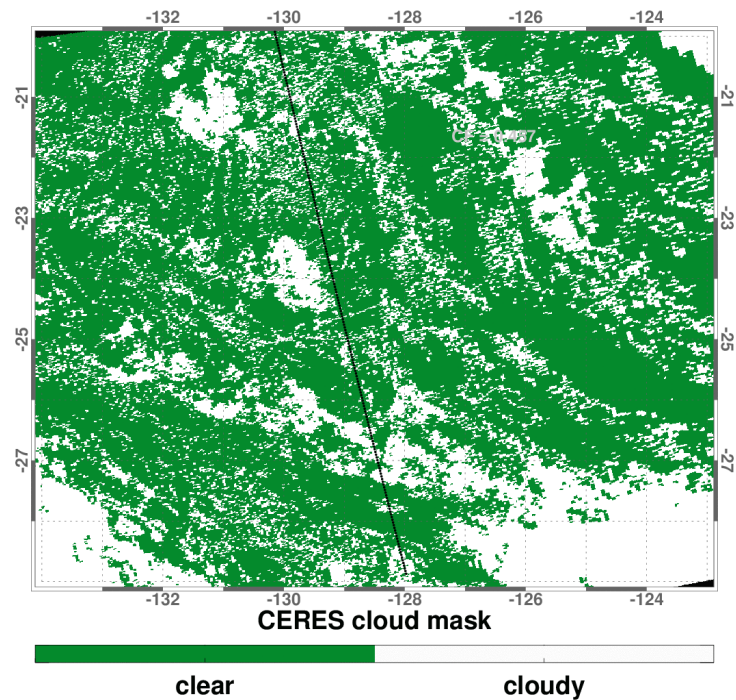
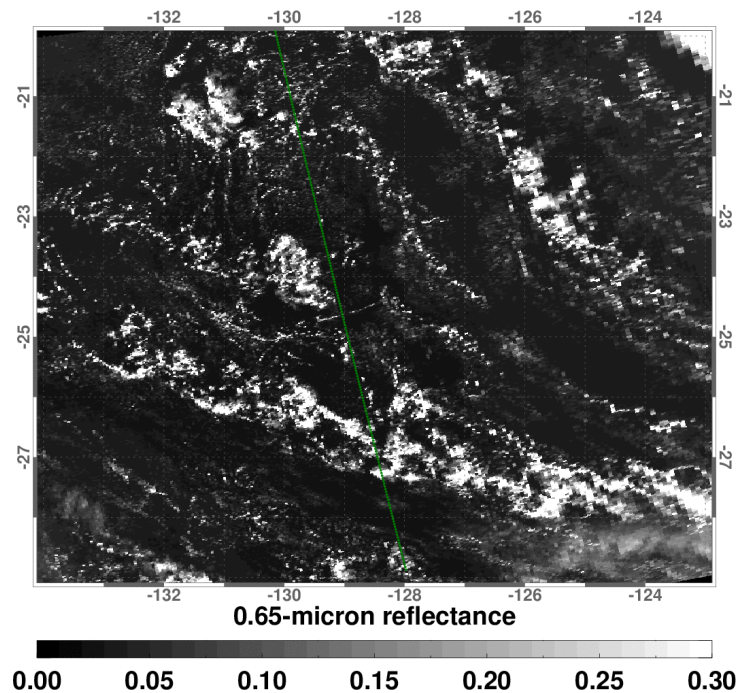
A significant portion of the undetected water clouds (green bars) were partially cloud-filled scenes

MODIS VIS Reflectance and Hit Rate as Function of Single-Shot Cloud Fraction



- MODIS has hit rates > 70% for mostly cloudy scenes
- MODIS VIS reflectance very small for CALIOP CF < 0.4 and often not high enough to trigger detection

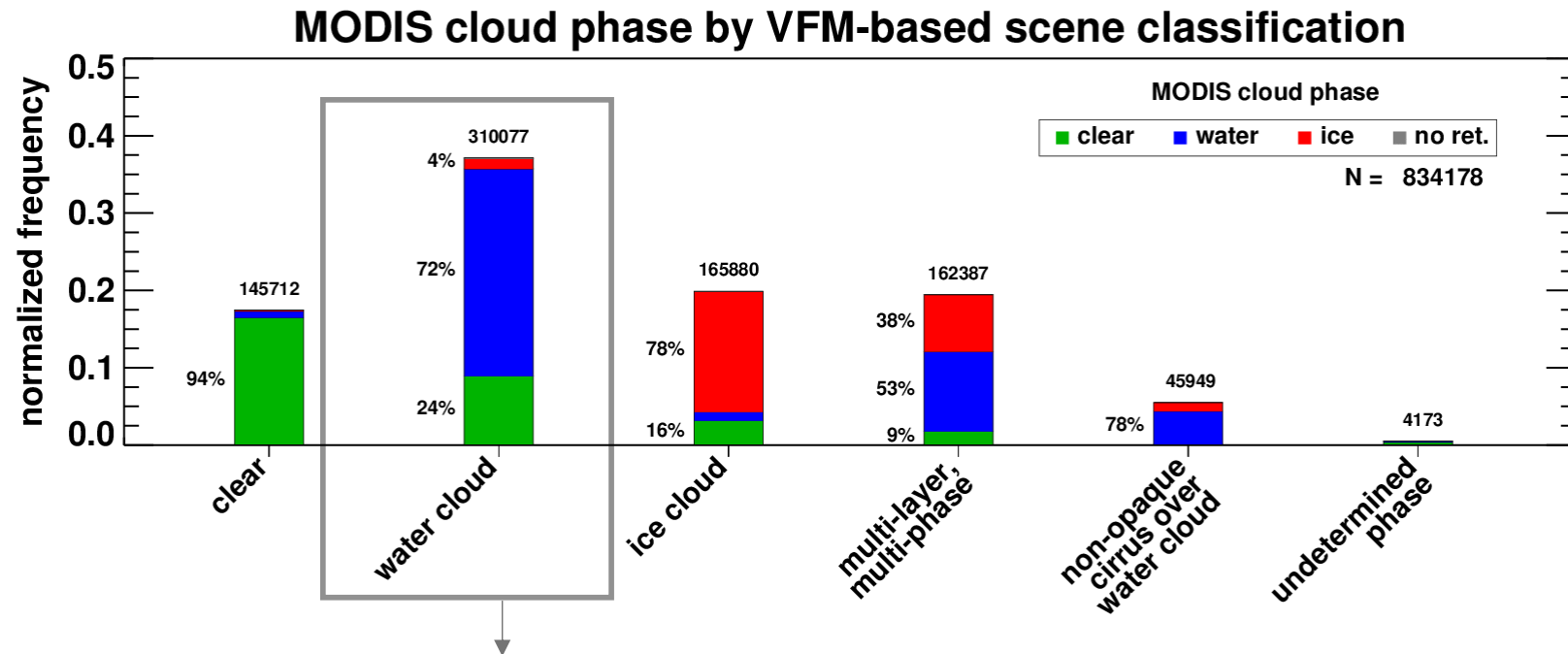
Example Case Study: April 3, 2010



	CAL HA \leq 80 km	CAL HA \leq 20 km	CAL HA \leq 5 km	CAL HA \leq 1 km	CAL single- shot only	MODIS
cloud fraction	0.35	0.35	0.35	0.35	0.21	0.33

- MODIS and CALIOP cloud fraction agree very well when 1-km and 5-km detections are included
- Only single-shot detections produce cloud fraction lower than MODIS
- When sensor spatial resolution is coarse compared to cloud elements, some over-estimation of cloud fraction is expected (e.g., Wielicki and Parker, 1992)

Cloud Fraction in Low-Level Water Cloud Scenes: April 2010



	CAL HA ≤ 80 km	CAL HA ≤ 20 km	CAL HA ≤ 5 km	CAL HA ≤ 1 km	CAL single- shot only	MODIS
cloud fraction	0.81	0.81	0.80	0.79	0.67	0.76

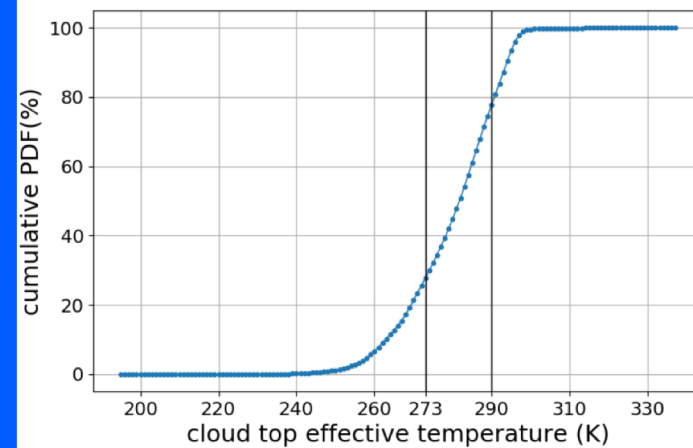
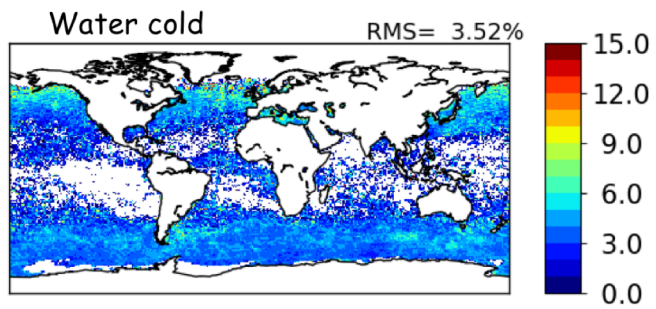
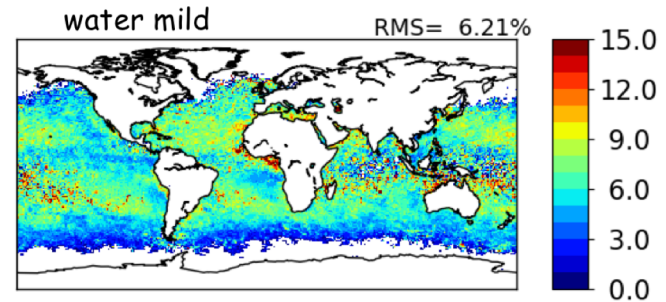
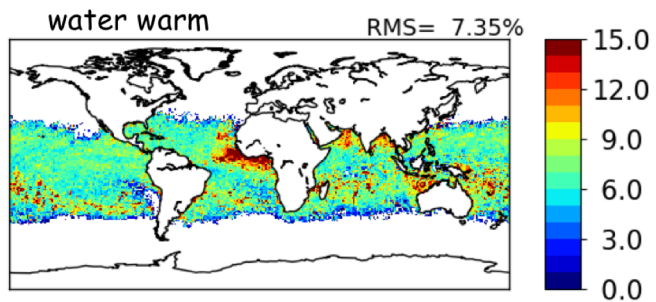
- Again, MODIS cloud fraction is high only relative to single-shot cloud fraction
- MODIS and CALIOP cloud fraction agree very well when 1-km and 5-km detections are included

Summary

- Does MODIS detect too many low-level clouds?
 - no, not at the native pixel resolution
 - CALIOP cloud fraction computed with 333-m, 1-km, and 5-km HA detections yield results similar to MODIS for low water clouds
- Does MODIS overestimate low cloud fraction?
 - Generally yes, when the cloud elements are smaller than the pixel resolution (1 km)
 - However, this is a known issue documented in the literature and not unique to MODIS
 - CALIOP single-shot cloud fraction is smaller than MODIS due to CALIOP spatial resolution/sampling (333-m spatial resolution)
- Resolved cloud fraction discrepancy with SARB group by agreeing on appropriate quality flag and horizontal averaging criteria (as seen in Seiji's talk on Tuesday, 5/15)
- For water clouds, CALIOP 333-m (single-shot) detections probably yield the best estimate of the true cloud fraction for low-level water clouds (top altitudes < 8.2 km)
- Future: Analyze cloud detection in polluted marine environments and for other cloud types
- CALIOP overestimation of high clouds detected at 20- and 80-km horizontal averaging?

Extra Slides

Next Subject: Cloud Detection in Polluted Marine Environments



Terra FM1 2001